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TECHNICAL EVALUATION OF THE FULL FACE MASK (FFM), SWIMMER LIFE --ETC(U)
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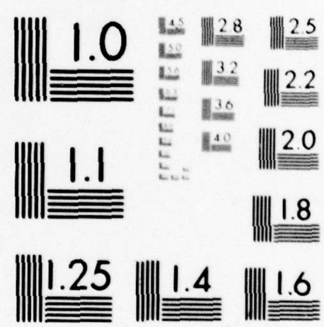

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Navy Experimental Diving Unit

DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407

IN REPLY REFER TO:

NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 6-79

TECHNICAL EVALUATION OF THE FULL FACE MASK

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September 1979

Approved for public release, distribution unlimited

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
NEDU Report No. 6-79

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER
9

4. TITLE (and Subtitle)
6 Technical Evaluation of the Full Face Mask (FFM), Swimmer Life Support System (SLSS).

5. TYPE OF REPORT & PERIOD COVERED
Final rept.

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
10 P. T. Smith

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Navy Experimental Diving Unit
Panama City, Florida 32407

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Program Element No. 63722;
Project ~~No. S6W07, No.~~ 3802

11. CONTROLLING OFFICE NAME AND ADDRESS

12. REPORT DATE
11 30 Sep[redacted]979

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
12 35

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited

14 NEDU-6-79

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Full Face Mask
MK 15 Mod 0 Underwater Breathing Apparatus
Swimmer Life Support System (SLSS)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Technical Evaluation (TECHEVAL) of the Full Face Mask was conducted to determine whether the mask functions in a technically acceptable manner and meets design and performance requirements of the Swimmer Life Support System (SLSS). This report compares component criteria and operational parameters with test results. Report concludes that the Full Face Mask met all requirements and is recommended for Operational Evaluation (OPEVAL).

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ABSTRACT

Technical Evaluation (TECHEVAL) of the Full Face Mask (FFM) was conducted to determine whether the mask functions in a technically acceptable manner and meets design and performance requirements of the Swimmer Life Support System (SLSS). The scope of the evaluation ranged from research and developmental testing through manned testing in the open sea using combat swimmers to evaluate the operability and maintainability of the mask. The FFM was designed and developed to interface with the MK 15 Mod 0 Underwater Breathing Apparatus (UBA) and test criteria were established which agree with the criteria for the MK 15 Mod 0 UBA. The mask successfully completed 618.5 hours of testing with no mission aborts attributed to the FFM. The mask meets the mission characteristics as specified in SOR 38-02 and NDCP 5-0417-SW. The FFM is recommended for Operational Evaluation (OPEVAL).

GLOSSARY

Abort	Premature termination of working dive after completion of setup, wet checkout, and approval of diving officer to start the dive. Aborts caused by factors external to the Full Face Mask will not be considered in computing mission or life support reliability
A_O	Operational availability
Sodasorb	CO_2 absorbent material
BPM	Breaths per minute
Bottom Time	Elapsed dive time from leaving the surface to leaving the bottom
CO_2	Carbon dioxide gas
Koegel Valve	Low resistance non-return valve
FSW	Feet of seawater
FFM (full face mask)	Face mask designed for the SLSS to provide tethered communications when working with swimmer delivery vehicles
Hazard	Any real or potential condition that can cause injury or death to personnel, or damage to or loss of system
Hazard Level	A qualitative measure of the degree to which a given failure represents a hazard to personnel and/or equipment <u>NEGLIGIBLE</u> . . will not result in personnel injury or system damage <u>MARGINAL</u> . . can be counteracted or controlled without injury to personnel or major system damage CRITICAL . . will cause personnel injury or major system damage, or will require immediate corrective action for prevention of personnel or system loss <u>CATASTROPHIC</u> . . will cause death or severe injury to personnel or system loss
Life Support Reliability (R_L)	The probability that, after system checkout, including diver's entry into water and diving officer's approval to start the dive, the life support system will carry the diver through his intended mission without abort due to critical or catastrophic hazard levels attributable to a life support system malfunction or design deficiency

GLOSSARY (Continued)

LSI	Logistic support index
Material Suitability Terms	For the purpose of this project, the following definitions shall apply: CRITICAL FAILURE . . Equipment is inoperative. No performance, or a critical or catastrophic hazard level exists MAJOR FAILURE . . Equipment is operable at a reduced level of effectiveness. A malfunction exists, performance is affected but the system can be used MINOR FAILURE . . The equipment is operable. Minor discrepancies exist but do not affect equipment performance
Mission	Scheduled dive together with assigned task or procedures
Mission Reliability (R_M)	The probability that, after system checkout, including diver's initial entry into water and diving officer's approval to start the dive, the system will carry the diver through his intended mission without abort attributable to a system malfunction or design deficiency
MTBF	Mean time between failures
MTFL	Mean time for fault location
MTTR	Mean time to repair
O.B.	Over-bottom, as in over-bottom pressure
OSF	Ocean Simulation Facility
Operating Time	Time during which the equipment is operating to specified standards in any mode for which it was designed. Minor faults may exist that do not significantly affect the equipment's ability to fulfill specified standards.
ΔP	Pressure differential
PPO_2	Partial pressure of oxygen
Predive Time	The time during which the diving system is actively undergoing predive checkout
Postdive Time	The time during which the diving system is actively undergoing postdive checkout

GLOSSARY (Continued)

psi	Pounds per square inch
psid	Pounds per square inch of differential pressure
psig	Pounds per square inch, gauge
scf	Standard cubic feet
S.E.	Surface equivalent
Reaction Time (T_R)	Time required to make preparations for the first dive of the day. T_R commences when diving station is fully manned and concludes when first diver commences his dive
Swimmer Delivery Vehicle (SDV)	A craft usually powered by batteries and an electric motor. Used as a means of transporting combat swimmers
Swimmer Life Support System (SLSS)	A number of equipments designed to provide the capability of meeting the requirements of SOR 38-02
Turnaround Time (T_T)	Time from completion of a dive to the time the same system is ready for a subsequent dive. Includes doffing, donning, and system predive checkout times
UBA	Underwater breathing apparatus
Underwater Decompression Computer (UDC)	A wrist-mounted computer which duplicates a diver's physiological condition with regard to gas absorption, and provides him with a safe decompression schedule

Figure 1. Full Face Mask

1. INTRODUCTION

1.1 SCOPE

This report documents the Technical Evaluation (TECHEVAL) of the Full Face Mask (FFM). The purpose of TECHEVAL was to determine whether the mask functions in a technically acceptable manner in a full range of operational modes and meets design and performance specifications. The evaluation shows that the full face mask (1) provides the combat swimmer with a communications capability, (2) interfaces with the MK 15 Mod 0 Underwater Breathing Apparatus, (3) provides additional thermal protection in the facial area, (4) reduces breathing resistance below that experienced with a conventional mouthbit, and (5) conforms to physical, technical, and mission characteristics and requirements specified in SOR 38-02 and NDCP S-0417-SW (reference 1).

The scope of the evaluation ranged from research and developmental testing through manned testing in the open sea to show operational effectiveness and suitability in the following areas:

- Diver mobility
- Dive duration
- Communications intelligibility
- Life support reliability
- Mission reliability
- Maintainability
- Availability
- Compatibility
- Interoperability

1.2 BACKGROUND

The Full Face Mask was designed and developed to interface with the MK 15 Mod 0 Underwater Breathing Apparatus and other equipments that have been developed or are being developed under reference 1.

To meet the requirements posed by the increasing complexities of diver mission assignments, the U.S. Navy conducted a commercial equipment survey of candidate diving masks in 1972 and 1973. Selecting the AGA mask for modification, development of a full face mask began at the Naval Coastal Systems Center (NCSC) in August, 1973.

The data necessary to demonstrate technical requirements for the FFM was collected during four separate test series, DT-IIB1, DT-IIB2, DT-IIIA, and DT-IIIB. The DT phases in which specific criteria were examined are outlined in paragraph 3.1. The same masks were used for all test phases. The only design changes were (1) following DT-IIB1 - modification of the nose clearing device, and (2) following DT-IIIA - addition of an O-ring on the shutoff valve and addition of the anti-fog chemicals.

Technical Evaluation of the FFM began with a series of experimental dives designed to test the mask's ability to support a diver performing sustained heavy work at operational depth. Conducted as a part of NEDU Deep Dive 77 and designated DT-IIB1, this test established breathing characteristics and demonstrated that the FFM can support a diver performing sustained heavy work at operational depths.

Technical Evaluation DT-IIIA was initiated in July 1978. This evaluation had to be cancelled due to problems resulting from fogging of the mask lens. Efforts to solve the fogging problem were undertaken in a series of dives (designated DT-IIB2) that eventually accumulated 117 hours of bottom time in the NEDU test pool and open water, Panama City, Florida.

The final phase of the TECHEVAL of the FFM, DT-IIIB, was conducted at the U.S. Naval Amphibious Base, Coronado, California using fleet support provided by Commander, Naval Special Warfare Group ONE. A total of 200 hours of manned testing in the open sea was logged during period 23 July to 17 August 1979. As part of DT-IIIB, testing of the mask's face seal in sea currents was accomplished at the Hyperbaric Research Laboratory of the State University of New York, in Buffalo, New York. Six hours of bottom time were accumulated during face seal testing.

The following, specific dives were accomplished at USNAB, Coronado, California during DT-IIIB to demonstrate operational suitability:

- Open water decompression dives to 150 FSW using a decending line
- Open water decompression dives to 150 FSW using SDVs
- Six hour open water dives using SDVs with a full complement of personnel
- Open water dives (in SDVs) requiring the use of available underwater communications equipment

1.3 FUNCTIONAL DESCRIPTION

Figure 2 shows the Full Face Mask and breathing hoses. The Full Face Mask performs the following functions.

- Forms a watertight envelope over the entire face with a wide-angle faceplate for vision.
- Provides a manifold with inlet and outlet non-return valves, a shutoff valve, and an inner oral-nasal mask to control the flow of breathing gases to and from the diver.
- Provides a nose-clearing device for equalizing pressure in the middle ear during descent.
- Contains a microphone for diver communications.

A five-strap head harness holds the mask in position on the face. Inhalation and exhalation hoses connect the mask's manifold assembly to the breathing apparatus. Upon inhalation, gas flows through a non-return (uni-directional) valve (right side) at the manifold inlet and then through a shut-off valve into the oral-nasal cavity where the diver inhales it. Exhaled breath passes back through the shutoff valve and exhaust non-return valve (left side) into the breathing apparatus via the exhalation hose. The diver may press against the bottom of the mask which causes the nose-clearing device to seal the nostrils and permits him to equalize pressure of the eustachian tubes and middle/inner ear recesses during descent. Plugging a communications cable into the mask's microphone connector permits voice communications while submerged. Closing the shutoff valve permits removal of the mask in the water without flooding the underwater breathing apparatus.

1.4 PHYSICAL CHARACTERISTICS

The physical characteristics of the Full Face Mask are:

Mask Body Material	Rubber
Manifold Assembly (incl shutoff valve body)	Aluminum
Shutoff Valve	Plastic (Delrin A-F)
Nose-Clearing Device (NCD)	Rubber-cushioned pad mounted on adjustable post
Non-Return Valve	Rubber, three-leafed conical valve (one-way Koegel valve)

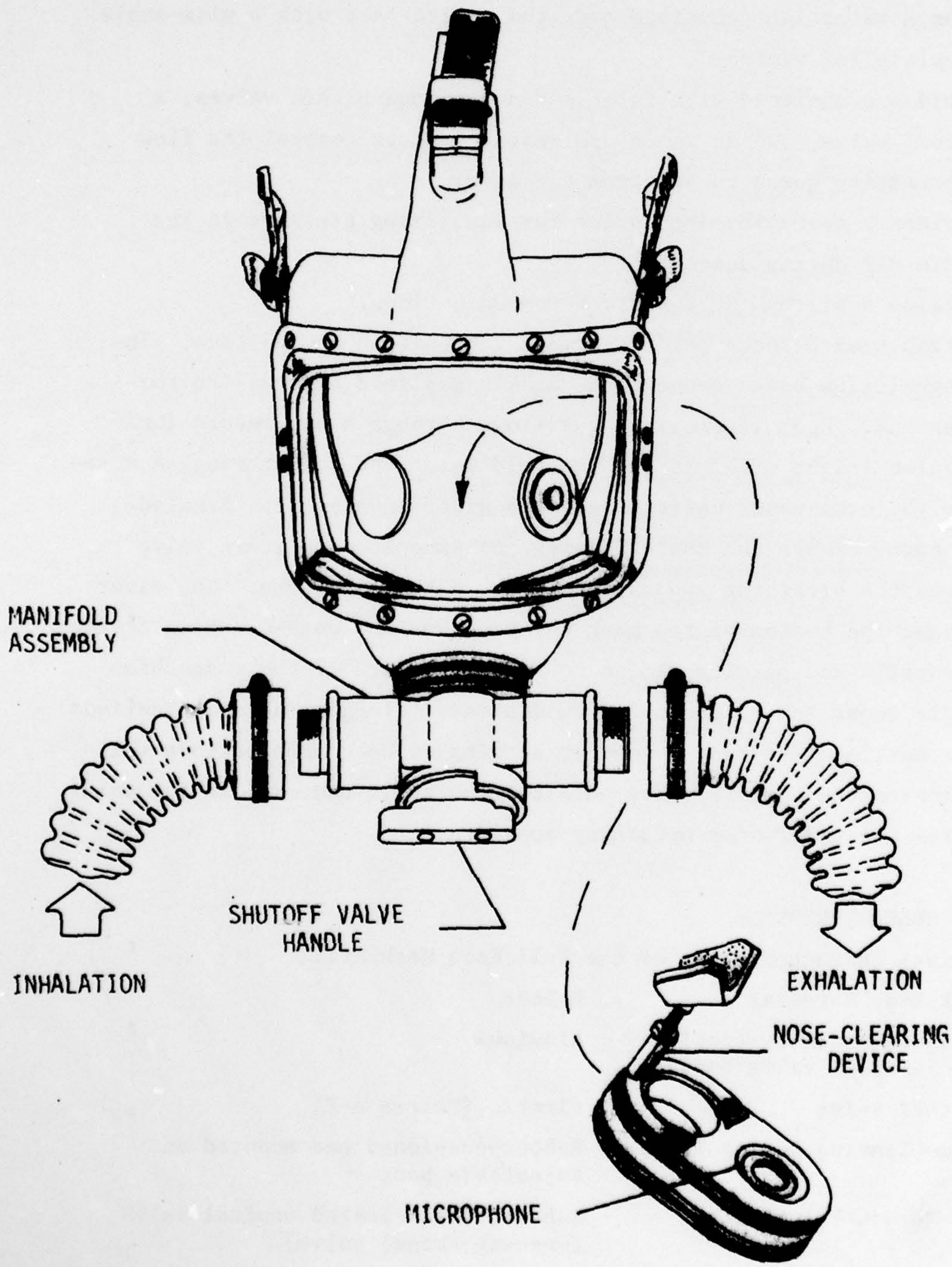

Figure 2. Full Face Mask with Breathing Hoses

Faceplate-visor	High-impact, shatterproof, polycarbonate plastic lens (built-in receptacles for wire frame eye glasses)
Microphone	Microphone with preamplifier
Size	One standard size, designed to fit most (approximately 95%) diver personnel
Design	Modified full face mask incorporating manifold and microphone assemblies developed by Naval Coastal Systems Center, Panama City, Florida

2. TEST PROGRAM

Manned testing was conducted to determine the effectiveness of the Full Face Mask and its compatibility with the MK 15 Mod 0 UBA in the following four areas:

- Swimmer Delivery Vehicle (SDV) operations
- Combat swimmer operations
- The ability of the combat swimmer to understand and perform proper maintenance procedures
- The provisions of adequate communications capability when used with existing equipment

The Technical Evaluation program consisted of four separate test series, outlined in paragraph 1.2, conducted from November 1977 to August 1979. The test criteria established for the test program agree with the thresholds and goals for the MK 15 Mod 0 UBA. The specific criteria established are shown below:

CRITERION NUMBER	THRESHOLD	GOAL
(1) Effective operating depth (ft)	150	150
(2) Maximum duration (hrs)	6	6
(3) Temperature range (°F)	40-93	29-93
(4) Face seal in sea currents (kn)	2	2
(5) Life support reliability (R_L)	.97 @ 95% confidence	.97 @ 95% confidence
(6) Mission support reliability (R_M)	.95 @ 80% confidence	.95 @ 80% confidence
(7) Mean Time Between Failures (MTBF) (hrs)	180	197
(8) Mean Time To Repair (MTTR) (hrs)	0.5	0.5
(9) Technical Availability	0.997	0.997
(10) Buoyancy when worn	neutral	neutral
(11) Maximum CO_2 dead space (ltrs)	0.3	0.3
(12) Breathing resistance not to be greater then MK 15 with standard mouthbit (cm H_2O) (ΔP total excursion)	20	20
(13) Intelligibility with SDV intercom (MRT raw score in %)	80	90
(14) Capacity to perform mission profiles	as required	

Personnel to conduct the test program were drawn from operational Underwater Demolition and SEAL Teams. NEDU provided the test director, diving supervisor, equipment technicians, and deep sea diving medical technicians.

Dives were conducted from 0 to 150 FSW with water temperatures ranging from 40°F (4°C) to 84°F (29°C). The test was conducted in a full range of dive profiles to include operations utilizing SDVs.

3. RESULTS AND DISCUSSION

3.1 GENERAL

Developmental testing and evaluation (DT&E) of the Full Face Mask was conducted in several phases to assess the mask's performance against performance specifications and by the criteria shown below. The summary identifies the phase of DT&E during which each criterion was evaluated.

CRITERION	DT&E PHASE
(1) Effective operating depth (ft)	DT-IIIB
(2) Maximum duration (hrs)	DT-IIIB
(3) Temperature range (°F)	DT-IIB2
(4) Face seal in sea currents (kn)	DT-IIIB
(5) Life support reliability (R_L)	DT-IIB1, DT-IIB2, DT-IIIA, DT-IIIB
(6) Mission support reliability (R_M)	DT-IIB1, DT-IIB2, DT-IIIA, DT-IIIB
(7) Mean Time Between Failures (MTBF)(hrs)	DT-IIB1, DT-IIB2, DT-IIIA, DT-IIIB
(8) Mean Time To Repair (MTTR)(hrs)	DT-IIIA
(9) Technical Availability	DT-IIB1, DT-IIB2, DT-IIIA, DT-IIIB
(10) Buoyancy when worn	DT-IIIA
(11) Maximum CO_2 dead space (ltrs)	DT-IIIA
(12) Breathing resistance not to be greater than MK 15 with standard mouthbit (cm H_2O)	DT-IIB1
(13) Intelligibility with SDV intercom (MRT raw score in %)	DT-IIIB
(14) Capacity to perform mission profiles	DT-IIB1, DT-IIB2, DT-IIIA, DT-IIIB

3.2 TEST CRITERIA RESULTS

Specific criteria are identified numerically below and correspond sequentially to the summary shown above.

3.2.1 Effective Operating Depth (Criterion 1)

Required	150 ft
TECHEVAL results	150 ft

The following dives were conducted to test the effective operating depth of the FFM:

- o To 150 feet on a descending line with 10 minutes bottom time (seven divers)
- o To 150 feet in a MK 8 SDV with 10 minutes bottom time (four divers)
- o To 150 feet in a MK 9 SDV with 10 minutes bottom time (two divers)

The dive profile used for these dives is contained in TM NAVSEA 0994-LP-016-1010, Operations and Maintenance Instructions for the MK 15 Mod 0 UBA (reference 2). The dives demonstrated the ability of combat swimmers equipped with the MK 15 Mod 0 UBA to follow a decompression schedule utilizing a descending line or a MK 8 or MK 9 SDV. All dives were successfully completed without equipment failure. It should be noted that during the SDV dives the SDVs had to leave the surface often to depths of 20 FSW while balancing the boats in preparation for the dive. This procedure adversely affects the ability of the diver to follow the MK 15 decompression tables. To preclude this problem, the diver must determine the expected time required to adjust buoyancy and trim. This time, when added to the desired bottom time, permits the use of the decompression schedule based on total time. If the SDV is trimmed prior to the preplanned time, the dive may begin; however, if the expected time for adjusting buoyancy and trim is exceeded, the decompression dive must be aborted.

3.2.2 Maximum Duration (Criterion 2)

Required	6 hrs
TECHEVAL results	6 hrs

To satisfy the criterion of 6-hour duration dives, two dive days were set aside in DT-IIIB for duration runs in the MK 8 and MK 9 SDVs. The lengths of SDV runs prior to the duration dives were progressively increased until diver confidence reached a point at which 6-hour runs could be attempted. Both the MK 8 and MK 9 duration runs were successful in the first attempt. Significantly, in the MK 8 SDV dive six divers were in the SDV for the first 2 hours 10 minutes of the dive, at which point one swim pair exited. These two divers reentered the SDV 4 hours and 20 minutes into the dive and remained until the mission was completed. Average diver gas consumptions during these dives were 1950 psi O_2 (13.6 scf) and 1125 psi diluent (7.9 scf). It should be noted that in preliminary dives the MK 9 crews had trouble fitting into the boat.

Divers who wore the Fenzy buoyancy compensators had greater problems with fitting into the MK 9 than those who wore the modified UDT life jacket. The problem is caused by the additional bulk of the Fenzy inflation bottle. The internal configuration of the MK 9 should be examined to determine where space can be saved.

3.2.3 Temperature Range (Criterion 3)

	Threshold	Goal
Required	40°F to 93°F	29°F to 93°F
TECHEVAL results	37°F to 84°F	

During DT-IIB2 testing to evaluate solutions to the fogging problem identified in DT-IIIA, tests were conducted in water temperatures ranging from 37°F (2.8°C) to 60°F (15.5°C) with no hindrance to the operation of the FFM. Other test dives were performed to a maximum of 84°F (29°C). The FFM was not subject to the maximum temperature limits of 93°F (34°C).

3.2.4 Face Seal in Sea Currents (Criterion 4)

Required	2 knots
TECHEVAL results	6 knots

The face seal testing, a part of DT-IIIB, was conducted at the Hyperbaric Research Laboratory of the University of Buffalo, Buffalo, New York, which has the facilities for generating and accurately measuring water currents. The facility has a circular pool with the capability to produce a 1.7-knot current for a stationary diver through the use of directional jets. It also possesses the capability to tow a diver to produce a 6-knot current. Six hours dive time was recorded in this test.

The stationary diver tests to a maximum of 1.7 knots were conducted with the diver held in position by a harness. Tests were conducted with the diver facing the current, with his side and then his back exposed to the current. These positions were utilized with the diver in the sitting position (simulating sitting in an SDV) and in a swimming attitude. Additionally, for each of the positions tested, the diver assumed four head positions: looking up, down, right and left. Each position was held for 15 seconds. None of these tests resulted in a mask leaking or being pulled off.

The towed diver tests were conducted to a maximum of 6 knots in the forward swimming position, sitting position facing forward and sitting with the back

facing the current. Maximum drag was measured at 265 pounds during these dives. Again, no mask leakage or pull-off occurred.

3.2.5 Reliability (Criteria 5, 6 and 7)

Required Life support reliability (R_L)	.97 @ 95% confidence	
TECHEVAL results (R_L)	.972 @ 95% confidence	
Required Mission support reliability (R_M)	.95 @ 80% confidence	
TECHEVAL results (R_M)	.978 @ 80% confidence	
	Threshold	Goal
Required Mean time between failures (MTBF) (hrs)	180	197
TECHEVAL results (MTBF)	210	

The following data were used to satisfy these criteria:

TEST	DIVES	HOURS
DT-IIB1	12	17.5
DT-IIB2	40	117.0
DT-IIIA	73	278.0
DT-IIIB	102	206.0
TOTAL	227	618.5

No failures causing mission abort occurred in any of the testing outlined above that were attributed to failure of the FFM. The total number of dives or missions completed (227) were used to compute the reliability criteria (R_L) and (R_M). Normally, MTBF would be computed using the total operating time divided by the number of major failures. Since no major failures were attributed to the FFM, the MTBF can be considered better than the 210 hours indicated. This MTBF considerably exceeds the goal established for the FFM.

3.2.6 Mean Time to Repair (Criterion 8)

Required	30 minutes (0.5 hr)
TECHEVAL results	25 minutes (0.42 hr)

This test was performed during DT-IIIA. Divers using a standard set of tools were able to completely disassemble the mask (less removal of the visor), lubricate O-rings and reassemble in an average time of 25 minutes.

3.2.7 Technical Availability (Criterion 9)

Required	.997
TECHEVAL results	.999

Technical availability was determined through use of the following formula:

$$\frac{MTBF}{(MTBF + MTTR)}$$

Using total dive time of 210 hours and MTTR (criterion 8) of 25 minutes, technical availability was computed to be greater than required by the test criterion.

3.2.8 Buoyancy (Criterion 10)

Required	neutral
TECHEVAL results	neutral to slightly positive

Buoyancy testing was performed during balanced dives in test evolution DT-IIIA and found to be neutral or slightly positive.

3.2.9 Maximum CO_2 Dead Space (Criterion 11)

Required	0.3 liter
TECHEVAL results	0.24 liter

This data was obtained during DT-IIIA. Measurements indicated the dead space to be approximately 0.24 liter depending on the size and shape of the diver's face.

3.2.10 Breathing Resistance (Criterion 12)

Required: Breathing resistance not to be greater than MK 15 with standard mouthbit, ΔP total excursion	20 cm H_2O
TECHEVAL results	17 cm H_2O

Breathing resistance of the FFM was evaluated during DT-IIB1. Detailed results of these tests are shown in NEDU Test Report 3-78 (reference 3). Figure 3 shows the oral-nasal differential pressure with graded exercise mean values for divers completing each work rate. At moderately heavy work rates (100 watts) which represent an underwater swimmer, the FFM meets the established criterion.

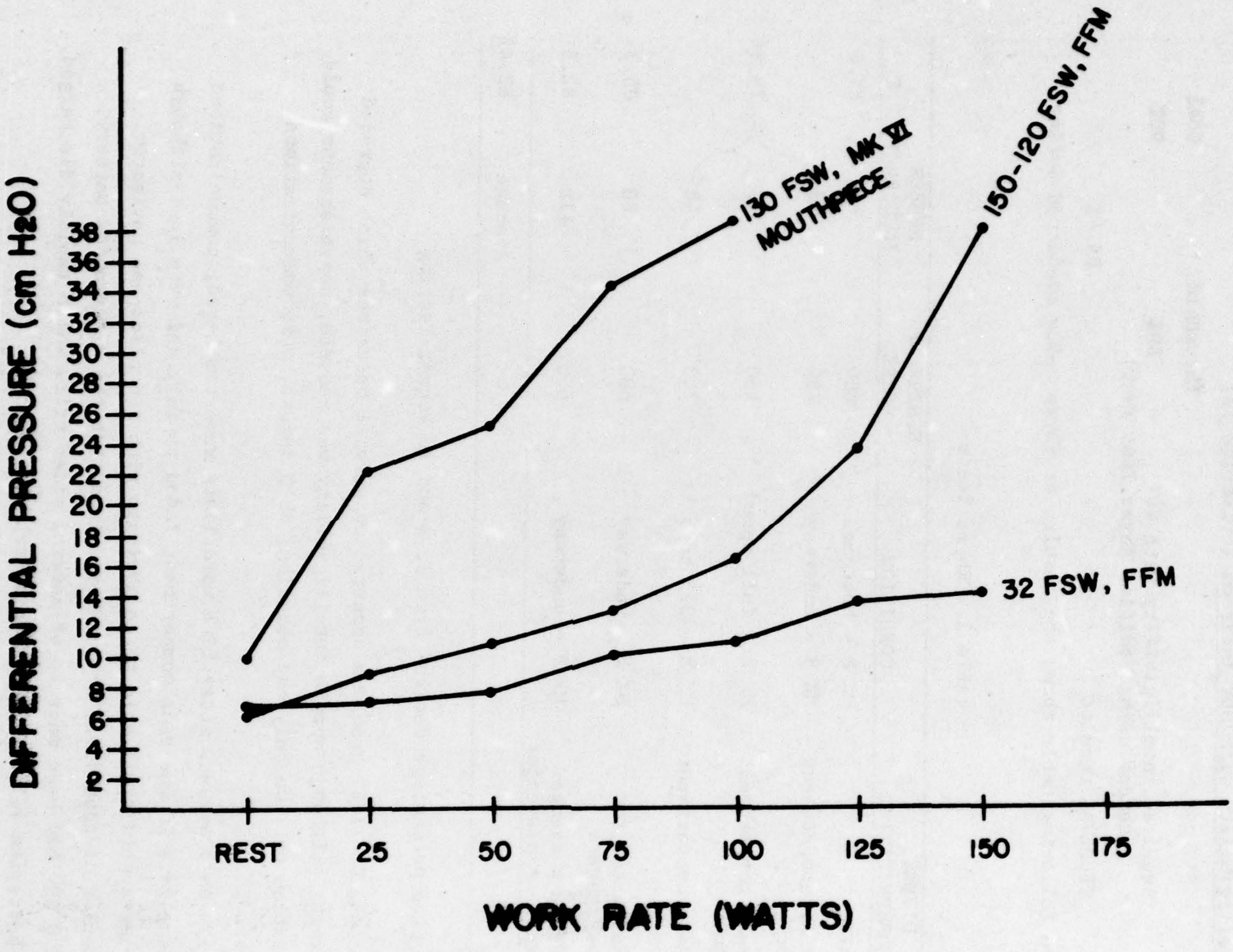

Figure 3. Oral-nasal Differential Pressure with Graded Exercise - Mean Values for Divers Completing Each Work Rate

3.2.11 Intelligibility with SDV Intercom (Criterion 13)

	Threshold	Goal
Required Intelligibility with SDV intercom using Modified Rhyme Test (MRT)	80%	90%
TECHEVAL results	82.4%	

a. The following table shows the results of Rhyme tests conducted during DT-IIIB:

Table 1. Rhyme Tests

DATE	DIVERS COMMUNICATING	CONDITION	NUMBER OF WORDS	NUMBER INCORRECT	%
1 Aug	All	MK 8 - bottomed	600	68	88.6
3 Aug	Rear compartment only	MK 8 - underway	250	33	
8 Aug	Rear compartment only	MK 8 - full speed	150	67	75.3*
10 Aug	Rear compartment only	MK 8 - 3.5 to 5 kt	200	48	
16 Aug	Navigator to passengers	MK 8 - underway	600	80	85.3
16 Aug	Front passenger to rear passenger	MK 8 - underway	600	118	82.3
				Average	82.4%

*Composite percentage derived from 3, 8 and 10 August Testing

b. During DT-IIIB, problems occurred on several occasions which degraded communications. Although speech intelligibility was reduced, conversations could still be carried on. On only one occasion, on 3 August, were communications totally lost.

(1) On 3 August, after five word lists were completed, communications between passengers in the rear compartment faded rapidly and were lost although both passengers were still able to communicate with the pilot and navigator. Upon completion of that dive, it was determined that the electronics battery for the MK 8 SDV had been made up of several older cells which rapidly discharged. Using new batteries will eliminate this problem.

(2) The results of MRTs showed that mechanical noise in the rear compartment of the SDV adversely affects those communications stations. It was assumed that the noise was being picked up through the aluminum manifold

and transmitted to the microphone. Adjusting the sensitivity of the pre-amplifier or noise attenuating circuitry is being considered as a method of noise reduction.

(3) While practicing depth control with the MK 9 SDV, communications were good initially but degraded as the dive progressed. The problem was traced to one diver who had water in the microphone recess of his mask. It was determined that a small hole, 0.125 inch, drilled between the microphone recess and the manifold gas port will allow drainage of the recess. This limited amount of water will not cause flooding of the canister.

(4) A high-pitched background squeal was present on several occasions during testing. It was found that the squeal increased during periods of no communication and was reduced or eliminated when voice transmissions were made. It is felt that the squeal resulted from audio feedback created as AGC circuitry increased amplification levels during periods when no communications occurred. It is recommended that AGC circuit sensitivity levels be reduced.

3.2.12 Mission Profile Performance (Criteria 14)

Capacity to perform mission profiles	As required
TECHEVAL results	Completed as required

The FFM effectively demonstrated its compatibility with the MK 15 Mod 0 UBA by successfully completing all attempted mission profiles.

a. Debriefing of divers and diver's comment sheets indicate that the FFM was rated good to excellent. Divers' comments and responses to specific questions are summarized in table 2. The diver comment sheet format is shown in Appendix A.

b. Analysis of divers' comments also revealed some problems relating to mask comfort, slight breathing resistance and side view distortion. It is noteworthy that mask discomfort and breathing resistance declined as divers gained experience and learned to adjust the MK 15 harness to conform to body attitude. The amount of adjustment varied depending on the individual build of the diver.

c. In the evaluation of criterion 14, several observations were made regarding the MK 8 SDV and the towing and handling system for both the MK 8 and MK 9 SDVs.

Table 2. Diver Comments
DT-IIIB

CONDITIONS CONSIDERED	COMMENTS	NO. OF RESPONSES	% OF RESPONSES
Mask Comfort	Very Uncomfortable	1	03
	Uncomfortable	8	29
	OK	6	21
	Comfortable	10	36
	Very Comfortable	3	11
Breathing Resistance	Excessive	0	0
	Moderate	0	0
	Slight	7	25
	None	21	75
Fogging	Yes	1	03
	No	27	97
Visual Problems	Severe	0	0
	Moderate	2	7
	Slight	10	36
	None	16	57
Water Enters Mask	Yes	4	14
	No	24	86
Intelligible Communications	Yes	18	87
	No	2	13
General Mask Performance	Unsatisfactory	0	0
	Poor	1	03
	Fair	2	07
	Good	22	79
	Excellent	3	11

During DT-IIIB problems were encountered in positioning three combat swimmers in the rear compartment of the MK 8 SDV. After experimentation it was determined that the best seating arrangement was as shown in figure 4 below:

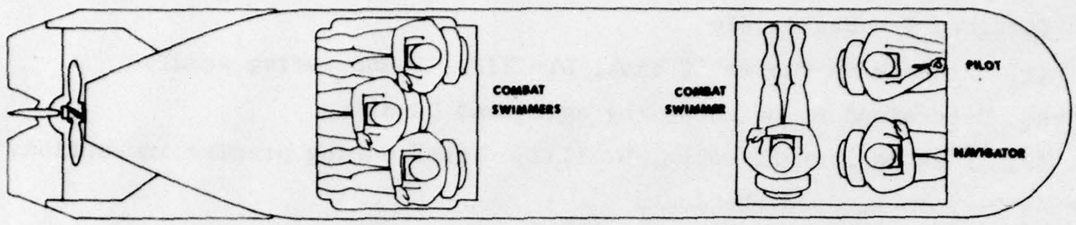

Figure 4. SDV Seating Arrangement

In passing the SDVs over the side of the LCU, both personnel and craft were exposed to excessive risks.

Difficulties were also experienced in towing the SDVs. The MK 9 did not tow well using a towing bridle. The boat continually attempted to dive. The strain caused broken and bent towing eyes. An SDV towing and handling system is presently under development at NCSC. This should reduce or eliminate the towing and handling problems experienced with the SDVs during DT-IIIB.

3.3 DISCUSSION OF FAILURES BY HAZARD LEVEL

3.3.1 Hazard Level Categories

Hazard levels established by MIL-STD-882 were used to evaluate problems/ failures encountered during TECHEVAL:

- Category I - negligible. Failure which will not result in personnel injury or system damage.
- Category II - marginal. Failure which can be counteracted or controlled without injury to personnel or major system damage.
- Category III - critical. Failure which will cause personnel injury, major system damage, or will require immediate corrective action for personnel or system survival.
- Category IV - catastrophic. Failures which will cause severe injury or death to personnel, or system loss.

3.3.2 Problems/Failures

Failures and problems encountered in the four tests supporting TECHEVAL are discussed below by category of hazard level. Assessment of a failure is based upon its resultant effect on the total system.

a. Category I - Negligible

(1) Pinhole in rubber of mask, DT-IIIB. Found during predive inspection. Determined to be caused by aging and handling.

(2) Leak in shutoff valve, DT-IIIB. Found during predive inspection. Lubricating O-rings stopped the leak.

(3) Leak in shutoff valve, DT-IIIB. Found during predive. O-rings replaced to stop the leak.

(4) Head strap broken while donning, DT-IIIB. Headstrap replaced.

(5) Self-locking straps on two masks showed signs of stretching, DT-IIIB. Found on predive. Although mask could not be separated from the manifold, the straps were replaced.

b. Category II - Marginal

(1) Fogging of the Full Face Mask during DT-IIIA. SDV pilots and navigators experienced difficulty in seeing instruments on several occasions due to fogging in the FFM, causing termination of DT-IIIA to allow for investigation of the problem. A market search was made for commercially available anti-fog solutions. DT-IIB2 was scheduled to evaluate the products available. A product called "Final Solution" produced by EXXENE Corporation of Addison, Illinois, was found to be far superior to all other products tested. This product washed off, however, when the mask was flooded. The manufacturer indicated he could permanently bond the anti-fog compound to the FFM lens. After several iterations were tested, one was found to be successful. This is a chemical composite consisting of a permanently bonded coating, applied by the chemist, and a wipe-on additive to be applied before each dive. Application time is 20-30 seconds. The anti-fog material has been tested for toxic off-gassing and found to be within limits as shown in table 3.

Table 3. Off-Gassing Evaluation of Anti-Fog Material

Components	Permanent Anti-Fog Coating	Non-permanent Liquid Anti-Fog Coating
Total hydrocarbons*	<1.0 ppm	<1.0 ppm
Total halogenated hydrocarbons	<0.5 ppm	<0.5 ppm
Methane	<0.1 ppm	<0.1 ppm
Ethane	<0.1 ppm	<0.1 ppm
Acetylene	<0.1 ppm	<0.1 ppm
Acetone	<0.1 ppm	<0.1 ppm
Benzene	<0.1 ppm	<0.1 ppm
C_4+	<0.25 ppm	<0.25 ppm

*Expressed as methane equivalent

(2) Communications problems have been discussed previously as they related to successful completion of criteria established for the FFM. Although communications were degraded at times, there were no mission aborts.

c. Category III - Critical

(1) During DT-IIIB, a potentially dangerous incident occurred involving the MK 15 Mod 0. While in the water preparing to dive, the MK 8 SDV intercom system was flooded and the vehicle had to be removed from the water to replace the intercom. The four divers participating in the dive remained on the surface for approximately 12 minutes. One diver turned off his electronics. When he reentered the water he failed to turn his electronics on. After entering the SDV and while preparing to close the rear compartment hatch, the diver went limp. His swim buddy recognized the diver had a problem and reacted immediately to bring him to the surface. In doing so, he experienced difficulty in removing the intercom connections from the diver. The endangered diver's disability was diagnosed as anoxia. Examination of his MK 15 UBA disclosed that the electronics were turned off. It was also noted that with the clandestine cover in place on the primary display, the diver was unable to determine the on-off status of his electronics. The diver recovered with no after effects. During the same dive, another diver inadvertently bumped the electronics switch to the off position. He developed a headache, and, in checking his equipment, discovered the problem. After turning the electronics back on, the situation stabilized. It is advisable during non-operational

dives to remove the clandestine cover from the electronics display to make the status and electronics readout readily visible to the diver. A check of tension of the electronic on-off switch should be included in the diver supervisor predive checklist. Again, it is emphasized that this problem is attributed to the MK 15 Mod 0, and not chargeable as a failure of the FFM.

d. Category IV - Catastrophic

No catastrophic failures of the Full Face Mask were encountered during TECHEVAL.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

4.1.1 The Full Face Mask successfully completed 618.5 hours of dive time with no mission aborts attributed to the mask.

4.1.2 All threshold criteria have been met or exceeded and all goals have been achieved except:

a. Testing in maximum water temperature of 93°F.

b. Attainment of an intelligibility score of 90% on the MRT. Failure to achieve the goal score of 90% can be attributed primarily to the SDV communications system rather than the FFM.

4.1.3 Developmental testing and evaluation has demonstrated that the FFM is compatible with and meets the technical characteristics required for the MK 15 Mod 0 Underwater Breathing Apparatus within the context of standards established for the Swimmer Life Support System.

4.2 RECOMMENDATION

Recommend the Full Face Mask be considered ready for OPEVAL in accordance with Test and Evaluation Master Plan No. 098-1.

5. REFERENCES

1. CNO OP-098, Navy Decision Coordinating Paper S-0417-SW, 23 August 1978.

2. Naval Sea Systems Command Technical Manual 0994-LP-016-1010, Operations and Maintenance Instructions, Underwater Breathing Apparatus, MK 15 Mod 0, p. 2-20, 1 November 1978.

3. Navy Experimental Diving Unit Report 3-78, Evaluation of a Full Face Mask for Incorporation into the Swimmer Life Support System MK 1, R. K. O'Bryan, 14 March 1978.

APPENDIX A

DT-III DIVER COMMENT SHEET

1. Instructions. This form is to be completed after each dive. Use additional comment sheets if necessary.

2. General.

   a. NAME____DIVER #__________

   b. TEST #________________ DATE __________________TIME__________________

   c. VISIBILITY: 0-3 ft.___ 3-10 ft.___ 10-30 ft.___ GREATER THAN 30 ft.___

3. FFM (Circle appropriate answer)

   a. Was the mask comfortable during the dive?

   very uncomfortable (1) uncomfortable (2) OK (3) comfortable (4) very comfortable (5)

   If uncomfortable, explain. ____

   ____

   ____

   b. Did you notice any breathing resistance?

   Excessive (1) Moderate (2) Slight (3) None (4)

   If breathing resistance was noticed, was it during exhalation (1) or inhalation? (2)

   c. Did mask fogging occur? YES (1) NO (2)

   If so, when? And did it prevent you from completing your assigned task? ____

   ____

   d. Did you notice any visual problems with the mask?

   Severe (1) Moderate (2) Slight (3) None (4)

   If so, explain. ____

   ____

   ____

APPENDIX A (Continued)

e. During your dives, did water enter the mask at any time? YES (1) NO (2)

If so, describe how much water, what caused it, did you have to surface, did it flood out the rig, were you able to clear the mask, would the addition of a purge or dump valve be of help, etc. ______________________

f. When using the communication system, were you being understood clearly and were you able to clearly understand when others talked to you?

YES (1) NO (2)

Explain. ______________________

g. In general, how would you rate the performance of the mask?

Unsatisfactory (1) Poor (2) Fair (3) Good (4) Excellent (5)

h. What suggestions do you have for improving the mask? ______________________

4. <u>UDC</u> (Circle the appropriate answer)

a. Was the UDC comfortable when worn on the forearm? YES (1) NO (2)

If uncomfortable, explain. ______________________

b. Did the UDC remain in a position to be easily read? YES (1) NO (2)

If NO, explain. ______________________

APPENDIX A (Continued)

c. Did wearing the UDC hinder your movements or was it cumbersome in any way? YES (1) NO (2)

If NO, explain. ______________________________

____

____

d. Did you encounter any problems in reading the display?

Severe	Moderate	Slight	None
(1)	(2)	(3)	(4)

If problems occurred, explain. ______________________________

____

____

____

e. If required to follow a decompression schedule, were you able to follow that schedule? YES (1) NO (2) Not required to follow schedule (3)

If NO, explain. ______________________________

____

____

f. Were you confident that the UDC was providing accurate information throughout the dive? YES (1) NO (2)

If NO, explain. ______________________________

____

____

g. In general, how would you rate the performance of the UDC?

Unsatisfactory	Poor	Fair	Good	Excellent
(1)	(2)	(3)	(4)	(5)

h. What suggestions do you have for improving the UDC? ______________________________

____

____

____

____

APPENDIX A (Continued)

5. Maintenance. If you performed any maintenance on your assigned units you should have completed a Ships Maintenance Action Form (2 Kilo). List job sequence numbers for maintenance actions taken for this dive.

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